Nationale Photovoltaiktagung 2004

Energieforschung und Umsetzung

Herausforderung in der

Technologie
Akzeptanz
Finanzierung

Louis Schlapbach
CEO Empa, CORE Mitglied

Gründe für Energieforschung und Umsetzung

- Langfristiges Erfüllen unserer Bedürfnisse für hohe Lebensqualität
  (Heizen, Kühlen, Mobilität, Transport, Maschinen, Geräte, Produktion)
- Nachhaltigkeit, Treibhausgase, Gesundheit
- Wirtschaftlich am Markt der Energietechnologie teilnehmen
- Innovative neue Produkte entwickeln
- Energietechnologie für Schwellenländer

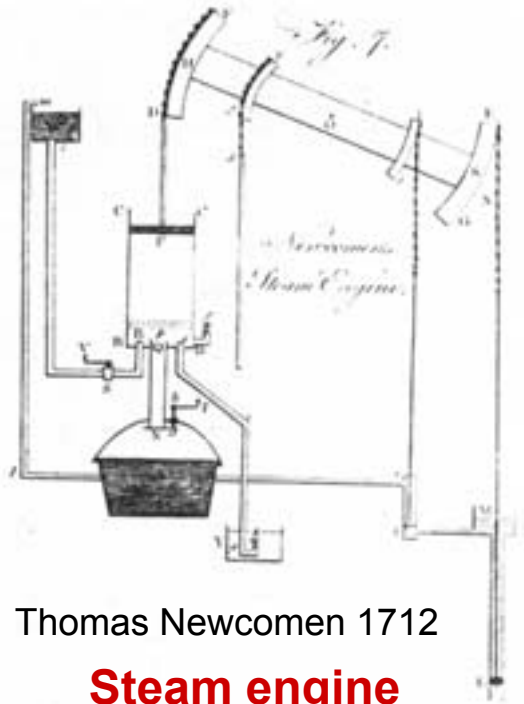
ENERGY RESOURCES

3000 B.C.

Human power
(0.1 kW/person)

1000 B.C.

Horse power



Thomas Newcomen 1712

Steam engine

1700

Carbon (C)

1800

Oil (-CH_2-)

1900

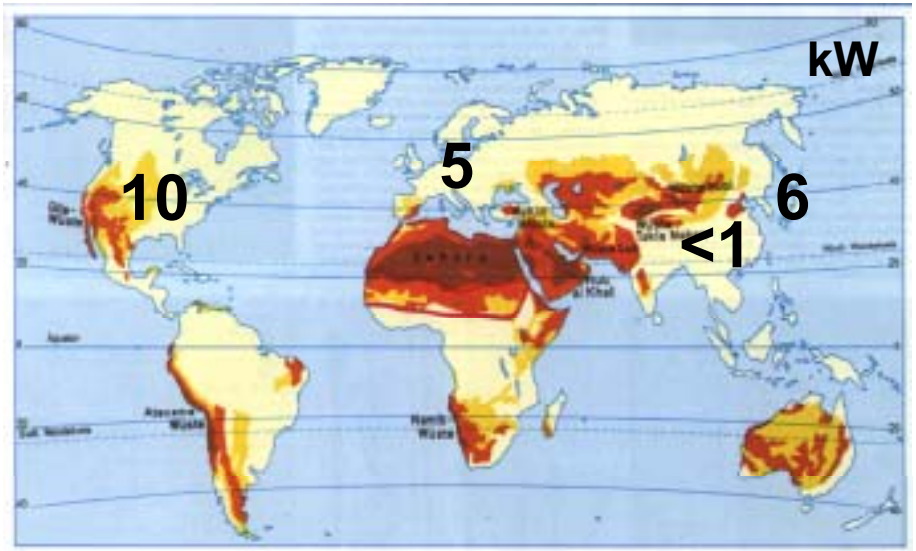
Natural gas (CH_4)

Andreas Züttel, University of Fribourg, 15.12.2002

ENERGY CONSUMPTION

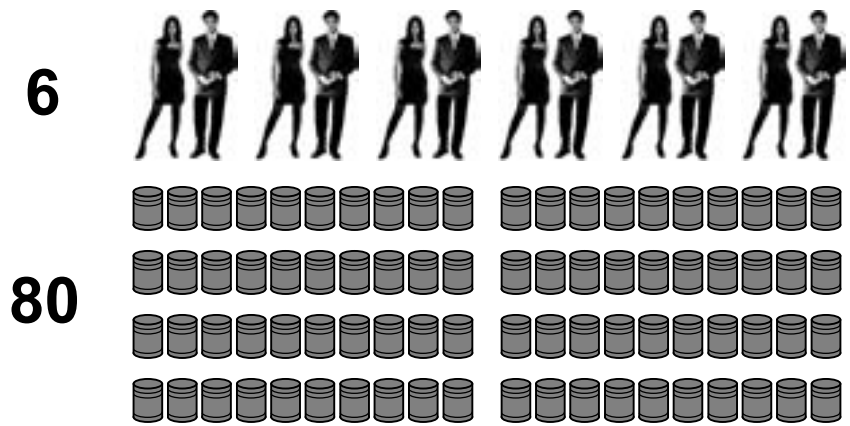
Energy carrier	Demand	Reserve [years]
Fossile		
Crude Oil	32.7 %	41
Natural Gas	19.5 %	63
Coal	21.4 %	218
Renewable		
Hydropower	6.7 %	
Biomass	11.6 %	
Others	2.0 %	
Nuclear	6.1 %	100

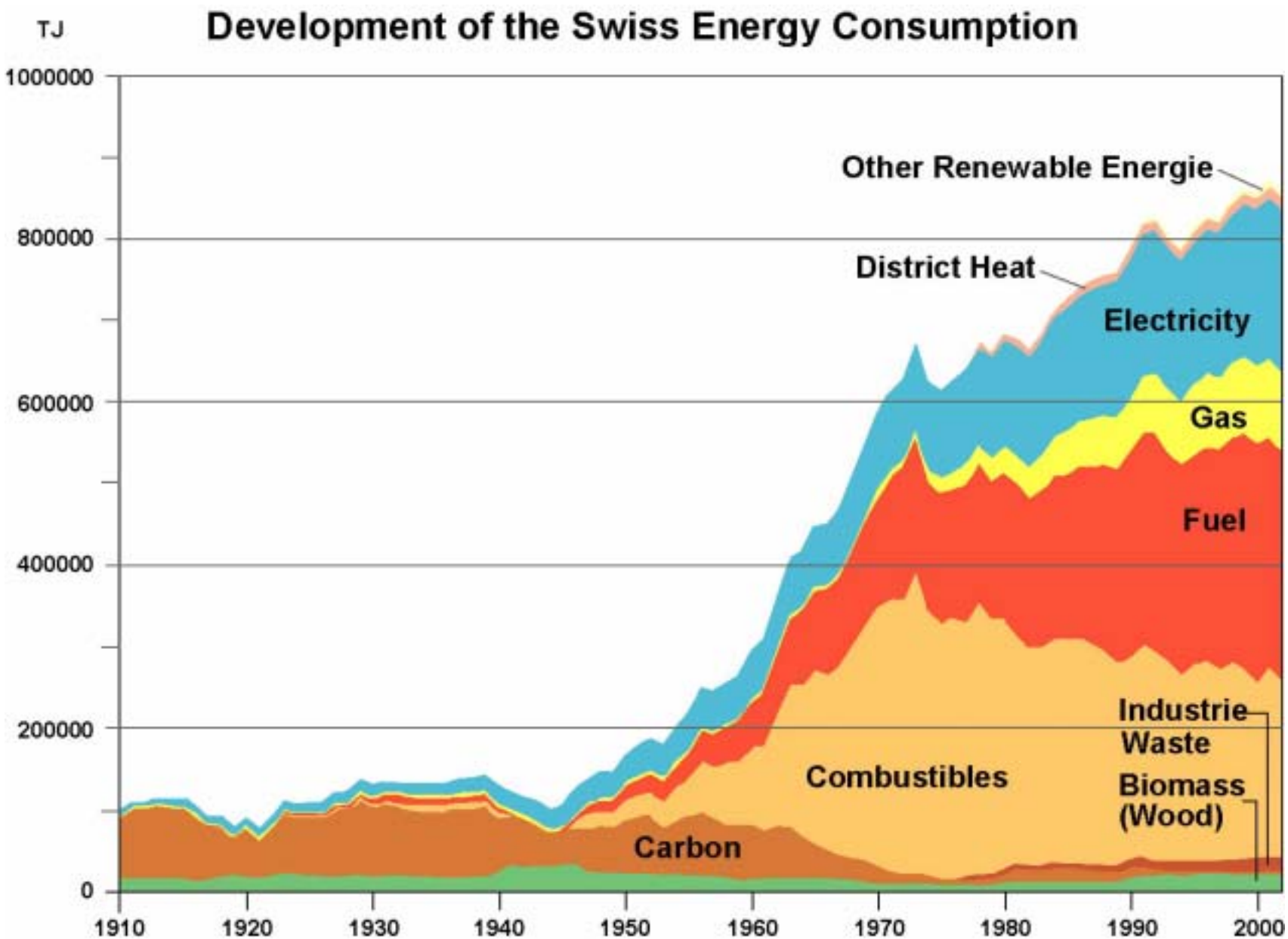
Average Power Consumption per Person



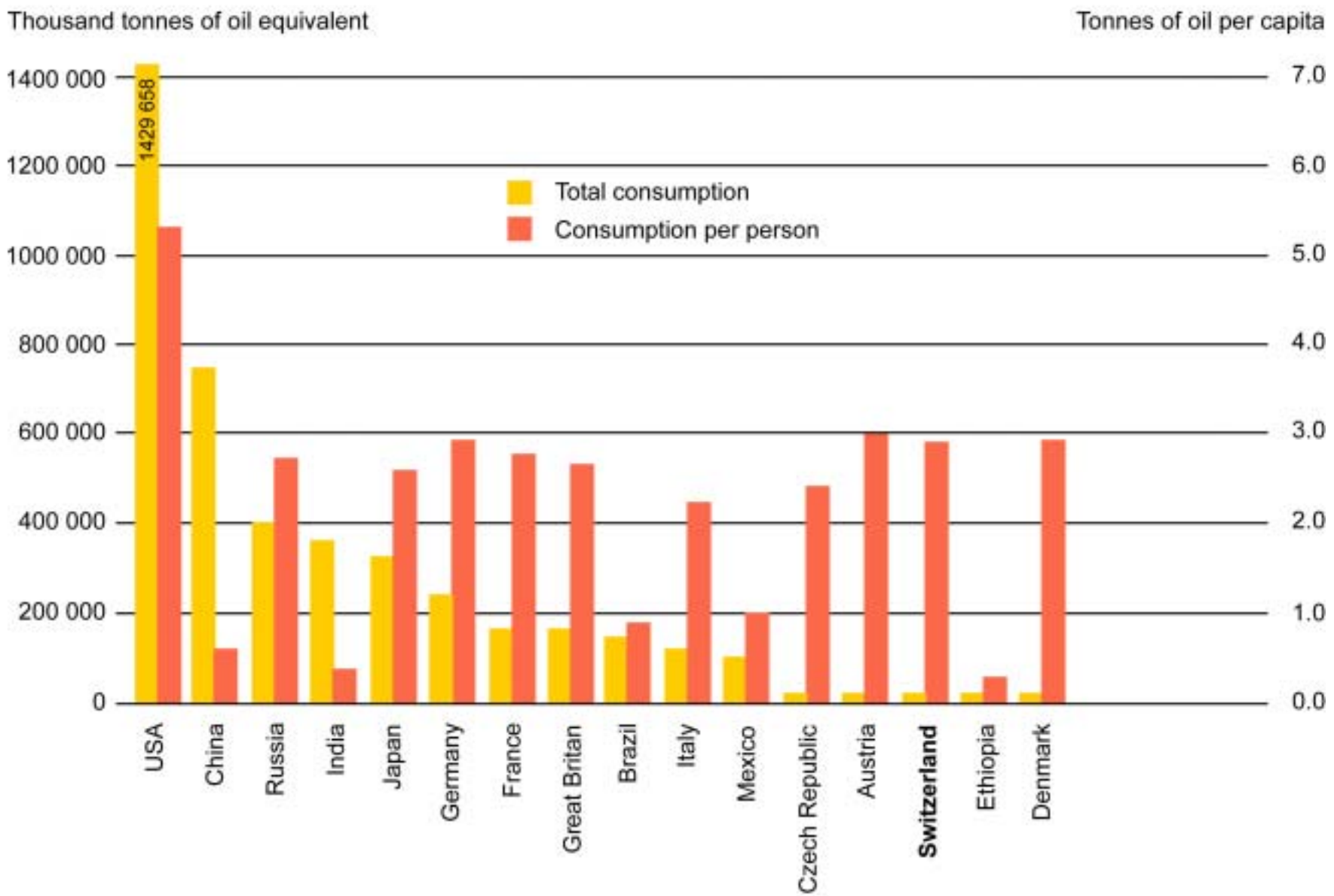
World = **2 kW/person** for 2 Bil. = **0 kW**

20th Century



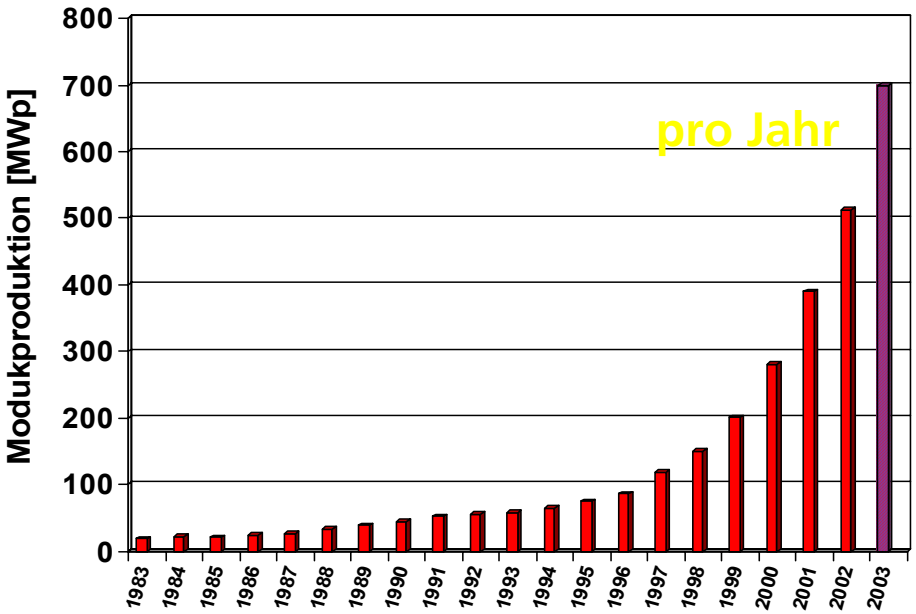

TJ
Development of the Swiss Energy Consumption
1000000
800000
600000
400000
200000
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Other Renewable Energie
District Heat
Electricity
Gas
Fuel
Industrie Waste
Biomass (Wood)
Combustibles
Carbon

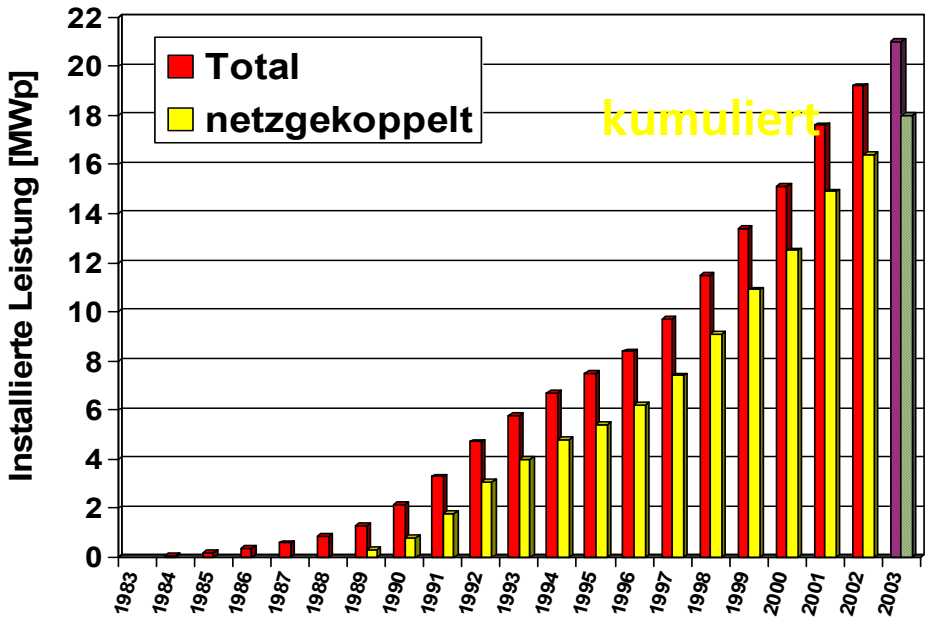
International comparison of energy consumption 1998



Source: International Energy Agency 2001

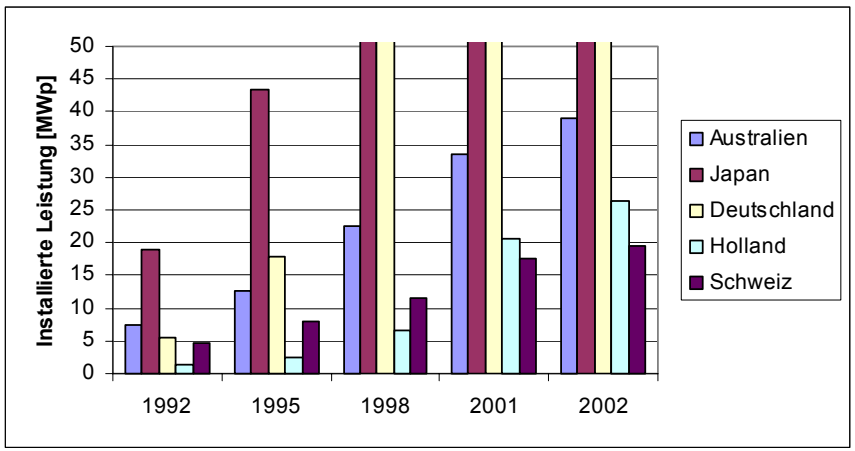
Der Photovoltaik Markt

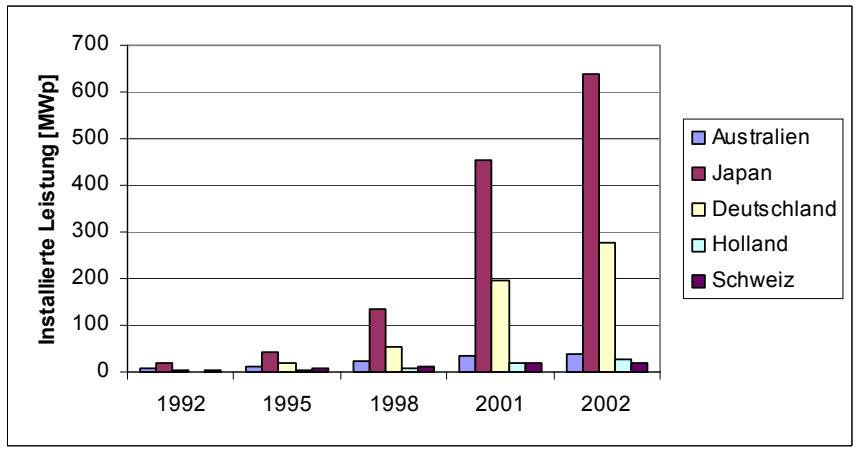


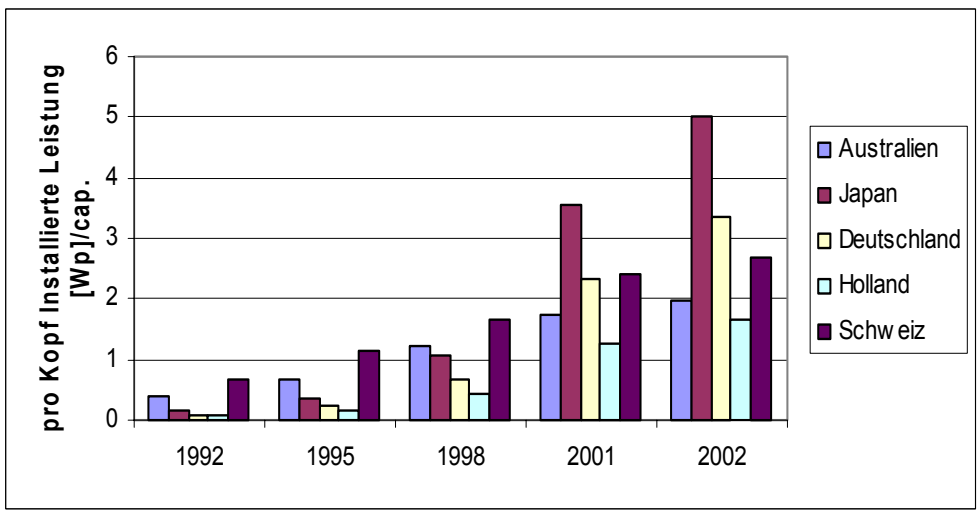


S. Novak

Vergleich total / per capita







S. Novak

The four main technology routes

RWE SCHOTT Solar

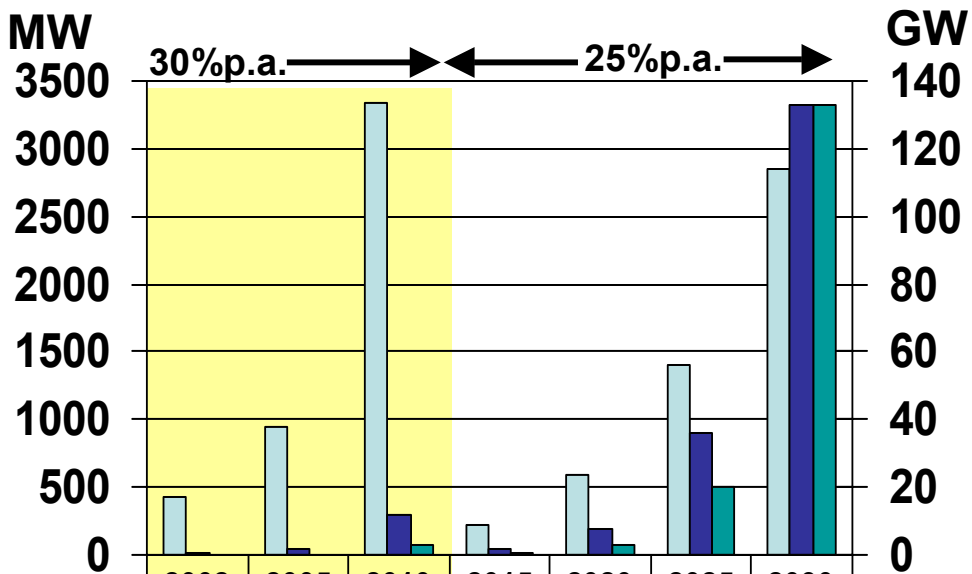
(a) Crystalline Silicon		(b)Thin Film	
Cz, Fz	High power/area @ premium price eta 16 - 25 % space, niche markets	II - VI compound (CIS, CTS) a-Si / µc-Si and thin Si films	Additional solutions for cost effective power applications eta 8 - 18 %
mc & ribbon (EFG)	Cost effective power application eta 14 - 16 % "The PV workhorse"	pin-ASI and ASI-THRU®	Low price/area @ low eta eta 4 - 6 % "Solar electricity glass"
(c) III - V compounds (GaAs)		(d) New Concepts	
"multi band gap" GaAs	Highest power/area @ very high price, eta 25 - 40 % space, concentrating systems	dye cells	"Colour to PV" (eta 3 - 10 %)
		organic cells	"low material cost option"
		Scientific high eta approaches aiming for eta 30 - 60 %	utilization of hot electrons, intermediate band cells, up/down conversion, quantum wells, nanostructures etc.

Production of Solar Modules using different Technologies

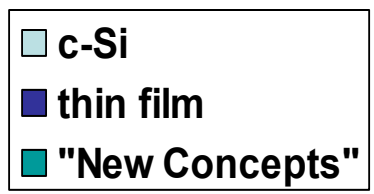
RWE SCHOTT Solar

2010 (Forecast)

Jp	1.200
EU	1.000
US	500
SOA	500
ROW	500
Σ	3.700



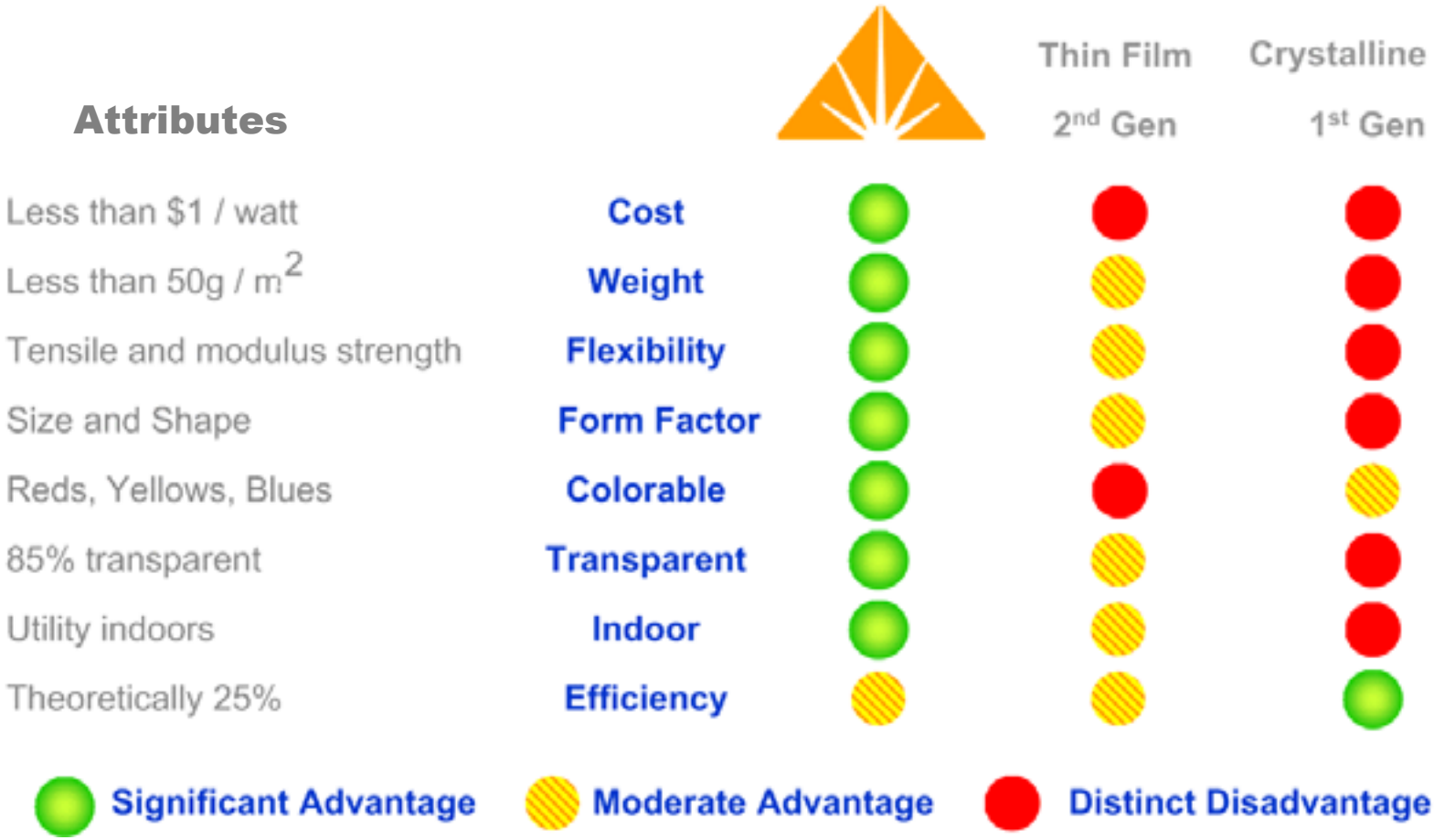
	2002	2005	2010	2015	2020	2025	2030
c-Si	430	950	3340				
thin film	20	50	290				
"New Concepts"			70				
c-Si				8.96	23.8	56	114
thin film				1.68	7.48	36	133
"New Concepts"				0.56	2.72	20	133



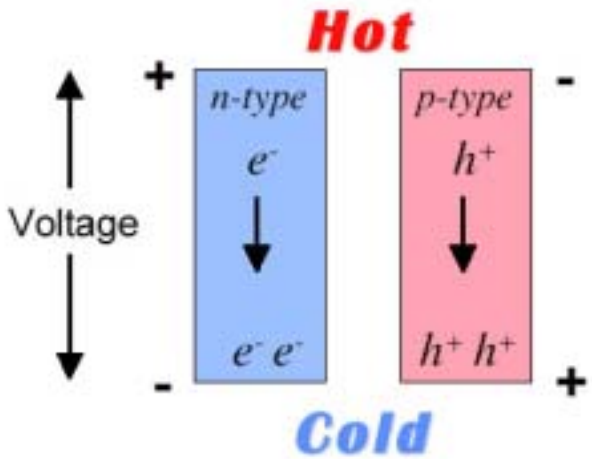
W. Hoffmann

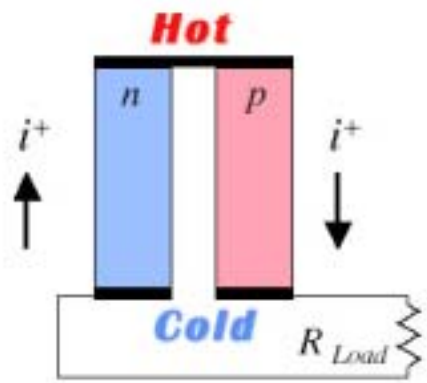
Changing the Solar Paradigm

Wireless distributed power becomes reality



Thermopower





Effect of Temp Gradient

Hot mobile species move faster

- $mv^2 = 3kT$
- Net diffusion to cold side

Establishes density gradient

- e.g. in a gas $\rho = n/V = (P/R) / T$
- Cold = dense Hot = rarefied

Charge buildup on cold side

- Forces carriers back
- Produces Voltage

  +/- depends on sign of carrier

Seebeck Voltage - Thermopower

$V = \alpha \Delta T$

- $-\boldsymbol{E} = \nabla V = \alpha \nabla T$
- Seebeck Coefficient α
- Produces electricity from Heat

The figure of merit *z*

$$z = \frac{\alpha^2 \cdot \sigma}{k}$$

The efficiency *h* of a thermoelectric device is related to *z*.

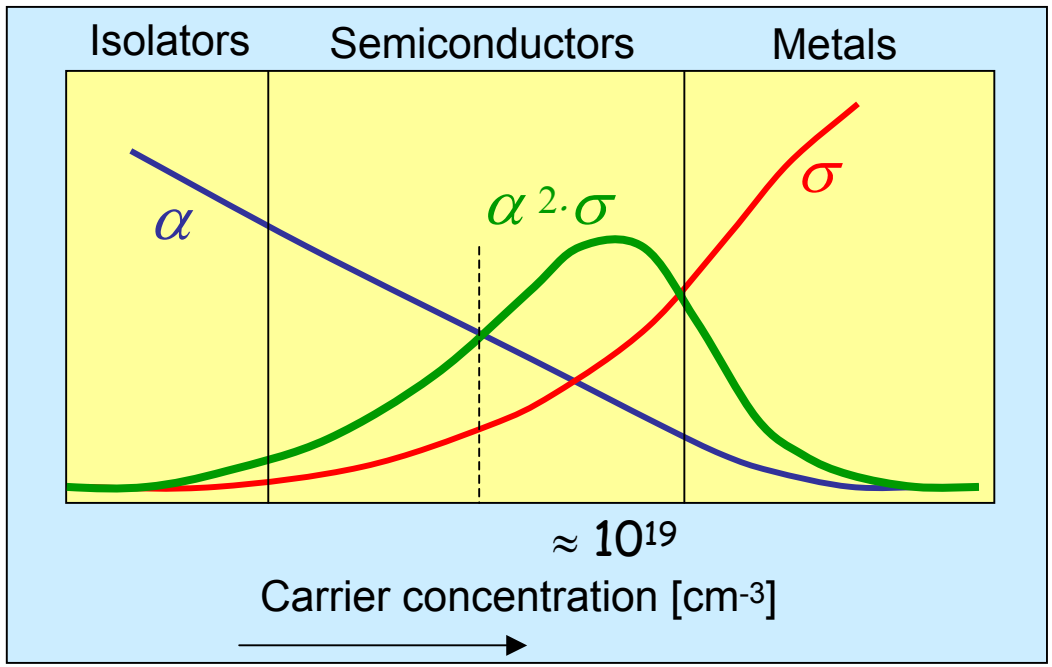
- For maximum device efficiency one needs to maximise *z* :

Seebeck coefficient α ↑

Electrical conductivity σ ↑

Thermal conductivity k ↓

($k = k_{lattice} + k_{electron}$)



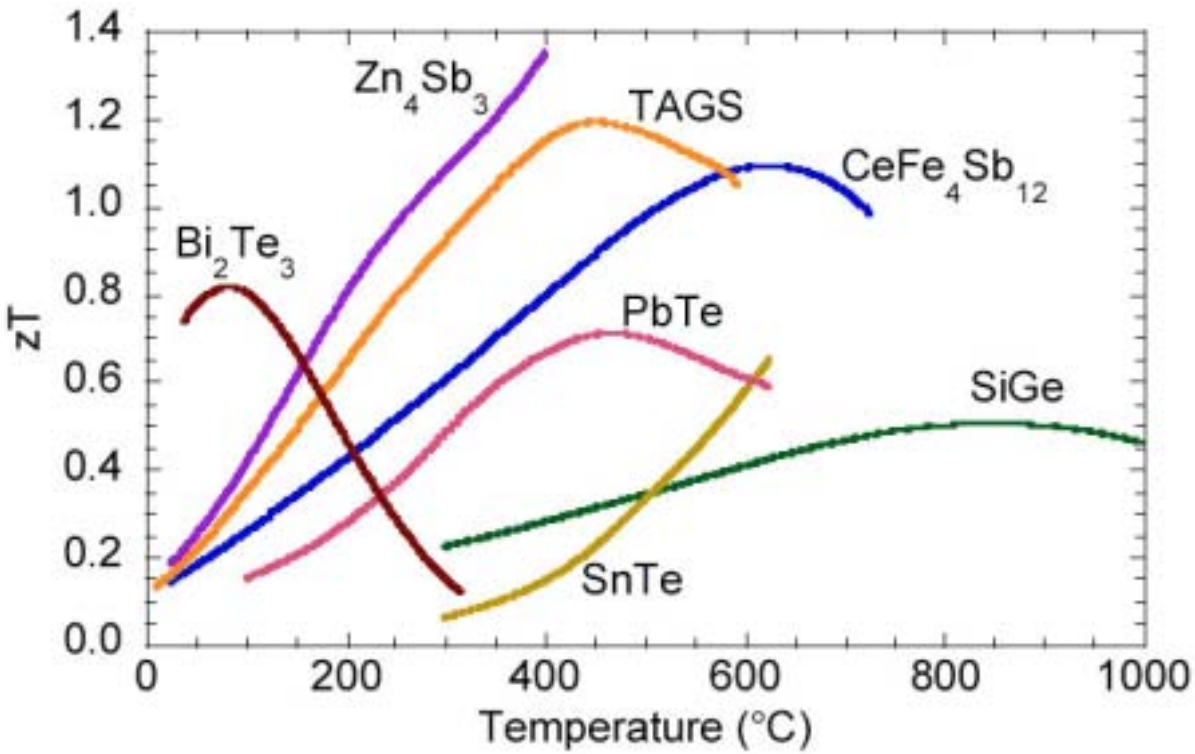
- Semiconductors with a carrier concentration of 10^{19} [cm^{-3}] satisfy the necessary criteria better than other materials .

EMPA

Advanced TE Materials

High zT materials

Do they have Electron Crystal - Phonon Glass properties?



Improved Segmented TAGS

TAGS has high zT - stable to 525°C

10.45% efficiency

n-PbTe stable to 600°C

525°C to 600°C p-type segment needed

p-PbTe has highest zT (before skutterudites)

But not compatible ($s_{PbTe} < 2\ s_{TAGS}$)

10.33% efficiency ***decrease***

p-SnTe has low zT, and some compatibility

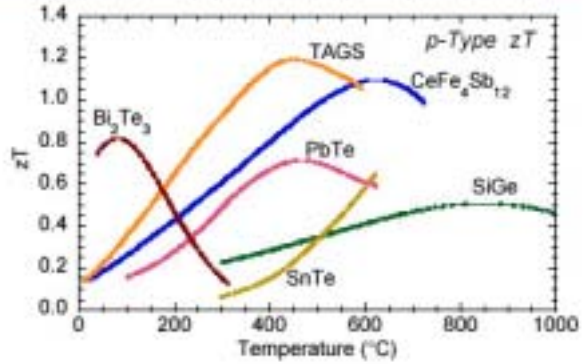
$s_{SnTe} \geq 2\ s_{TAGS}$

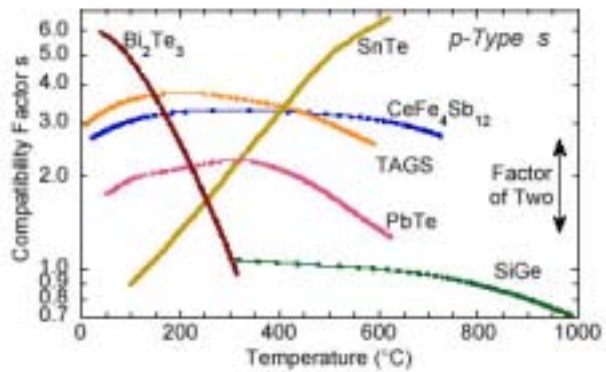
11.09% small efficiency increase

p-Skutterudite has high zT, *and compatibility*

11.87% large efficiency increase

13.56% for 700°C hot side





Material	*Efficiency (%)*	T_c *(C)*	$T_{boundary}$ *(C)*	T_h *(C)*	$u(T_z)$ (V^{-1})
p-TAGS	10.45	100		525	2.97
p-TAGS/PbTe	10.33	100	525	600	2.33
p-TAGS/SnTe	11.09	100	525	600	2.84
p-TAGS/$CeFe_4Sb_{12}$	11.87	100	525	600	2.94
p-TAGS/$CeFe_4Sb_{12}$	13.56	100	525	700	2.88

G. J. Snyder *Applied Phys. Lett.* **Mar 22** (2004)